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Acoustic Measurement and Model Predictions for the Aural Nondetectability of Two Night-Vision Goggles

by Jeremy Gaston, Tim Mermagen, and Kelly Dickerson

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14. ABSTRACT

This study evaluates two different night-vision goggles (NVGs) to determine if the devices meet level II aural nondetectability standards of MIL-STD-1474D for a detection distance of 10 m. These systems (PVS-14 and PVS-7D) were tested while mounted on an Advanced Combat Helmet placed on the Knowles Electronic Manikin for Acoustic Research Auditory Test Fixture in the Environment for Auditory Research's Dome Room, a semi-anechoic research space. All tests were conducted in both the linear and automatic gain control (AGC) modes of operation for each system, and measurements were made at eight locations around the devices. The results of the testing revealed that in the linear mode, both devices emitted a faint tone centered at 2 kHz, but in no case did the NVGs fail the nondetectability criteria of 10 m. In AGC mode, both systems emitted a tone but the PVS-14 did not fail the nondetectability criteria. However, the PVS-7D failed the 10-m detection criteria at several of the measurement positions.

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auditory detection, acoustic measurement, aural nondetectability, night-vision goggles

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1. Background

An important concern in the use of any equipment is the how the operational characteristics of that equipment will affect the Soldier's acoustic footprint. This is especially true when stealth is required, such as in night operations under low light conditions, where the use of night-vision goggles (NVGs) is critical to performing safely and effectively. The present work is an evaluation of the aural nondetectability of two NVG devices in common operational modes. The two devices are the PVS-14, a single-tube monocular NVG, and the PVS-7D, a single-tube biocular NVG. Both devices operate in a linear mode under low light conditions (no active gating to limit incoming light levels) and have an automatic gain control (AGC) where active gating limits incoming light levels to protect the image intensifier tube if exposed to intense light. Anecdotal reports by NVG users have complained of an audible tone produced by the PVS-7D when in the ACG mode. The present evaluation was conducted to predict probable acoustic detection of the PVS-14 and PVS-7D using the aural nondetectability criteria outlined in MIL-STD-1474D (Department of Defense, 1997); these criteria are based on applications of the Auditory Detection Model (ADM) described in Garinther et al. (1985).

Whether or not a sound will be detected depends on a number of factors, including the distance from the sound source, and a number of environmental factors (Garinther et al., 1985), but ultimately what matters for detection is the signal-to-noise ratio (SNR) between the level of a sound source and the ambient background at the listener location. Auditory masking is when the presence of a sound prevents the detection of another sound. The phenomenon of auditory masking provides the basis for models that predict the detectability of sound sources by listeners. A discussion of auditory masking will be presented followed by a brief discussion of how the Auditory Detection Model (ADM) (Garinther et al., 1985) estimates masking to predict the distance at which a sound would be detected. Finally, the application of the model described in MIL-STD 1474D will be discussed. The aural nondetectability of the two NVGs in the present work is evaluated using the criteria described in MIL-STD-1474D.

1.1 Auditory Peripheral Masking and the Critical Band

The human peripheral auditory system processes sound in an overlapping bank of auditory filters (Fletcher, 1940). Auditory masking of a signal depends only on the energy within a given filter; any energy outside of that filter will not contribute any additional masking. In the classic masking paradigm to estimate the size of the auditory filter, a target tone of a specific frequency is played. At the same time, a narrow-band white-noise masker is played and varied in bandwidth. The listener's task is to respond whether or not he/she hears (detects) the target tone. The result is that there is a monotonic increase in target tone-detection level as a function of masker bandwidth, but at some critical masker bandwidth the slope approaches and stays at zero. Thus, the masker contributes no additional masking. This "critical bandwidth" (CB) then defines the edges of a given auditory filter centered at a given frequency. For simplicity, Fletcher assumed the shape of the CB to be rectangular, and defined the CB as the "equivalent rectangular bandwidth" (ERB). The shape of the CB is better approximated by implementing a roex filter (Patterson et al., 1982), and the bandwidth increases nonlinearly as intensity increases (Moore, 2003), but the ERB still represents a reasonable approximation of the CB. Above 500 Hz, the size of the ERB increases by a multiplicative relationship (Moore, 2003). Below 500 Hz, the size of the ERB is roughly constant with a bandwidth of about 100 Hz (Zwicker, 1961). Zwicker (see Hartmann, 1998) defines the size of successive ERB's as fixed widths in a look-up table, but Moore (2003, page 73) provides a formula for estimating the size of the ERB for a given center frequency:

$$ERB_N = 24.7(4.3F+1) \tag{1}$$

where the value of ERB_N is in hertz and the value of F is in kilohertz.

For further simplicity, the size of successive ERBs can be estimated using 1/3-octave bands (Moore, 2003). In musical intervals, successive octaves follow a multiplicative relationship, each successive octave a doubling in the previous octave frequency.

1.2 Auditory Detection Model (ADM)

The auditory detection model (ADM) is based on parameters described in Garinther et al. (1985). The basic model makes the simplifying assumption that the shape of the auditory filters are 1/3 octaves. The inputs of the model are the recorded 1/3-octave levels of a sound source from a fixed distance and fixed source height. Additional inputs include measurements of listener hearing threshold, ambient background sound levels, environmental temperature and humidity, and estimates of ground reflectivity. For simplicity, atmospheric effects such as changes in temperature gradients and wind conditions are assumed to be neutral, and thus represent a worst-case detection scenario. Given these parameters, the model gives a prediction of probable detection distance for a given input sound source. Consistent with classic auditory masking research, the ADM predictions evaluate detection as a function of the signal-to-noise ratio within each 1/3-octave band (estimate of the CB).

1.3 Aural Nondetectabilty: MIL-STD-1474D

The present study evaluates aural nondetectability of the two NVG devices as outlined by MIL-STD-1474D, the parameters described in which were derived from the ADM (Garinther et al., 1985) using default model parameters. The default temperature was selected to be 15° C; the default humidity was selected to be 70%; and the default ground effect was selected to be consistent with grass. Tables were developed for two different background levels. The first, level I, was consistent with a rural farm located at least 4 km from road traffic with no insect noise. The second, level II, represented the quietest noise environment likely to be encountered, at least 16 km away from road traffic and no insect noise. These background levels were taken from Environmental Protection Agency measurements (1971); the level II measurements were made at the north rim of the Grand Canyon. The tables in MIL-STD-1474D list the detection limits in 1/3-octave bands for a number of distances as a function of various measurement distances. In the present study, the criteria evaluated against were listener detection at 10 m given a measurement distance of 2 m for level II background levels. Measurement set height was 1.2 m.

2. Method

2.1 Location

2.1.1 Dome Room

All acoustic testing was conducted in the Dome Room of the U.S. Army Research Laboratory Environment for Auditory Research facility (see Henry et al., 2009, for a full description of the facility). The Dome Room is a semi-anechoic space designed for conducting auditory research and testing. The space measures 6.6 × 8.1 × 4.1 m in height. The noise floor of the Dome Room meets NC-15 noise criteria requirements. Figure 1 shows the noise floor of the Dome Room on the day of testing in 1/3-octave bands compared with 1/3-octave band values of the level II ambient noise level described in MIL-STD-1474D. Note that up to 4 kHz the noise floor of the Dome Room is below the levels described in MIL-STD-1474D; above 4 kHz the noise floor is slightly above, but not by more than 2.5 dB at frequencies up to 10 kHz. In all cases, measured signal levels while the NVGs were in AGC mode were always at least 10 dB greater than the Dome Room noise floor.

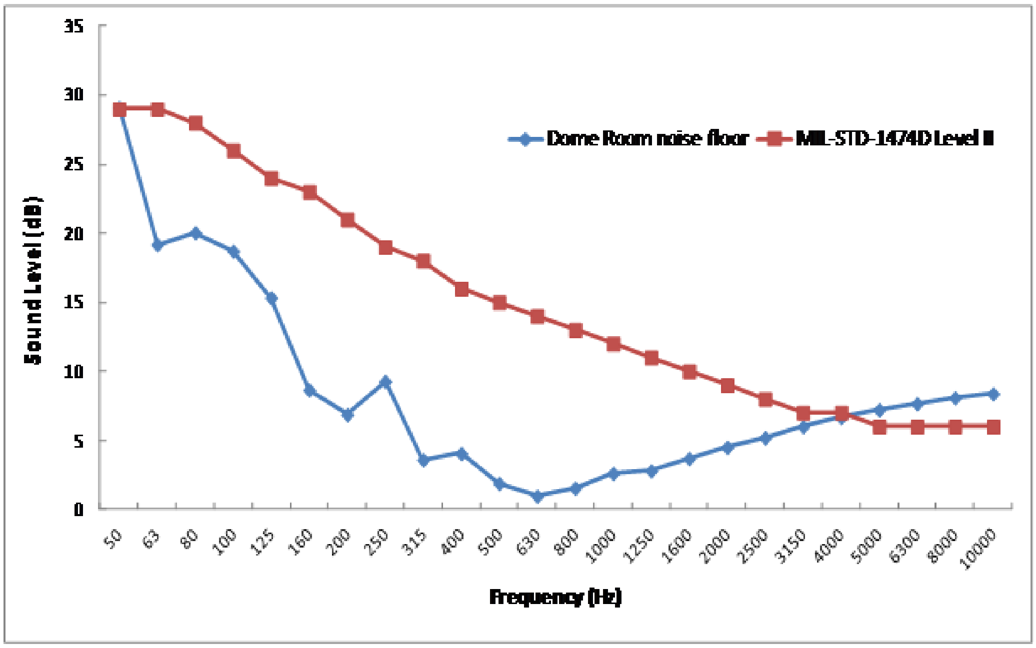

Figure 1. Dome Room noise floor versus MIL-STD-1474D level II ambient noise levels in 1/3-octave band levels.

2.2 Apparatus and Procedure

2.2.1 Equipment

All recording procedures were conducted in accordance with ANSI S1.13 (2010) and MIL-STD-1474D. Recordings were made using two G.R.A.S. 40-AF 1/2-in free-field microphones with preamplifiers. Each microphone was powered by a G.R.A.S. 12-AK power supply. Microphones were then connected to a Presonus Firestudio recording interface, which was connected to a laptop PC by firewire. In addition, recordings were made from the left and right ears of a KEMAR acoustic test fixture (ATF) that uses ER-11 microphones and DB-100 Zwislocki couplers. All recordings (24 bit, 96 kHz) were acquired using Adobe Audition 3.0. The KEMAR and 40-AF microphones were calibrated using a G.R.A.S. 42-AA calibrator set using a 250-Hz tone at 114-dB sound pressure level (SPL). Two NVG systems were tested. The PVS-7D is a biocular device with two eyepieces; the PVS-14 is a monocular device with one eyepiece. Both systems provided monocular input and had two standard modes of operation, linear and AGC.

2.3 Recording Setup

Each NVG was first mounted on an Advanced Combat Helmet, which was placed on the KEMAR ATF (see figure 2). Measurements were simultaneously made from two of the 40-AF microphones and KEMAR’s left and right ears. The 40-AF microphones were placed at fixed relative positions labeled 0° and 180°, respectively (see figure 3). In order to make measurements at eight positions around the NVG devices (0°–315° in 45° increments), KEMAR was rotated about a central point in the Dome Room. Measurements were made across these eight positions to evaluate the directivity of sound output for each device in each mode of operation. The center of KEMAR’s ear canals and the center of the 40-AF microphone diaphragms were set at 1.2 m above the floor. The 40-AF microphones always faced the mounted NVG device at a 90° incidence. In addition, the 40-AF microphones were placed 2 m from the center of the NVG devices. Thus, as KEMAR was rotated, slight adjustments were made in the 40-AF microphone positions to maintain a 2 m to center alignment. For each measurement, at least 10 s of sound data were collected for later analysis.

Figure 2. PVS-7D (left) and PVS-14 (right) mounted on the KEMAR ATF in the Dome Room. (Note that NVG apertures are covered to protect devices from photographic light.)

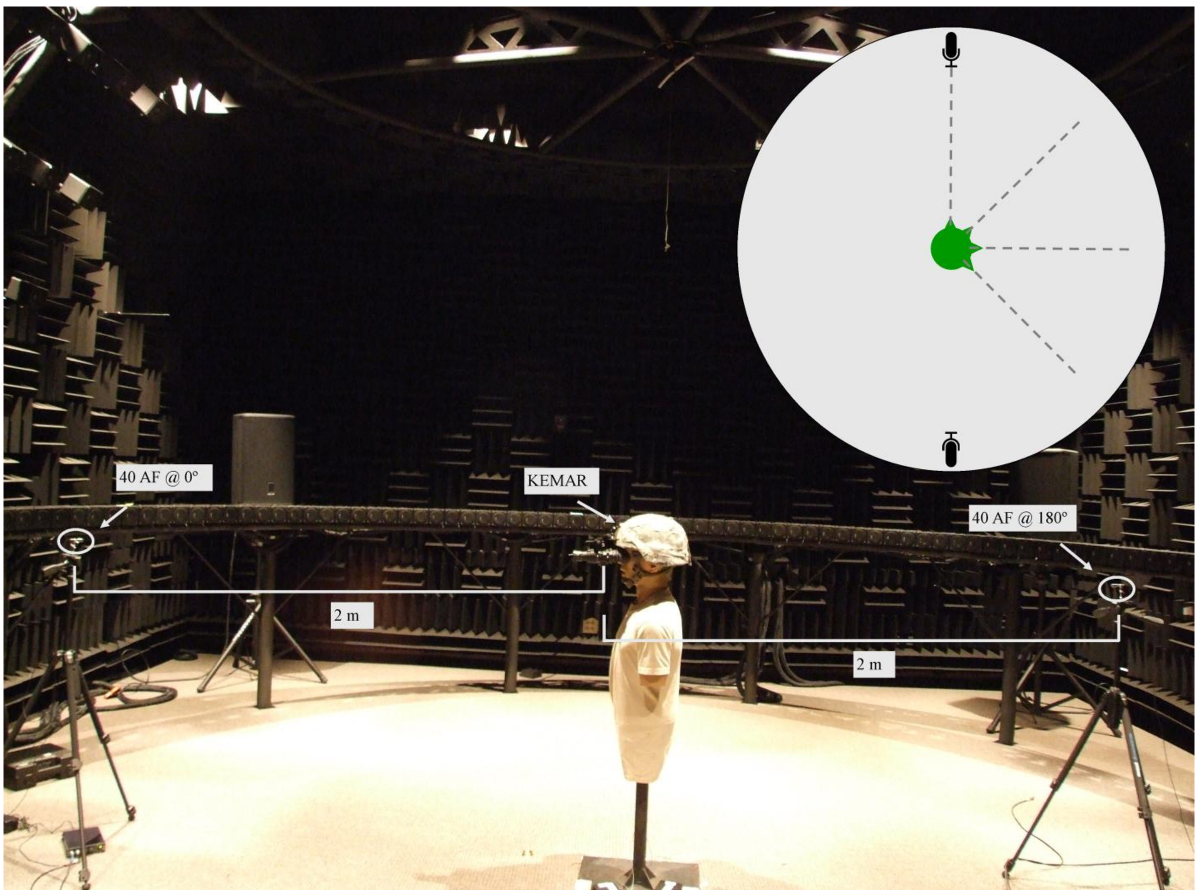

Figure 3. KEMAR ATF positioned in the center of the Dome Room and facing 0°. The dashed lines in the insert to the top right depict the four KEMAR facings made to collect the eight measurement positions around the respective NVG device.

2.4 Measurement Conditions

Testing was conducted in two sessions, one in the morning and one in the afternoon. Before each session, a calibration tone was recorded for each of the four microphones. The individual calibrations tones were used to calibrate the measured signals collected in the respective sessions. The first part of each session consisted of ambient measurements of the Dome Room to determine the noise floor and act as a reference for subsequent measurements of the NVG modes (linear and AGC). Second, measurements were made for the four KEMAR facings (thus eight positions) in the linear mode of the NVG. Third, measurements were made for the four KEMAR facings in the AGC mode. Mode adjustments were always made by a qualified engineer familiar with the systems.

In the morning session, the PVS-14 was measured using low ambient lighting conditions consisting of a single bank of fully dimmed lights in both the linear and AGC modes. This bank of lights was sufficient to trigger the AGC mode of the PVS-14. In the afternoon session when PVS-7D was measured, the lighting conditions differed from those used for the PVS-14. The PVS-7D's linear mode measurements required minimal lighting, which consisted of only the illumination from several green and red light-emitting diode indicators on the recording equipment power supplies. However, to make measurements for the AGC mode for the PVS-7D, the device required a fully illuminated room with an additional light source illuminating a background with changes in contrast. To accomplish this, a poster board with significant changes in contrast was propped in front of the NVG without blocking the sound pathway to the 40-AF microphones. To minimize reflections off of the poster surface, a set of acoustically absorptive foam wedges was placed over the majority of the poster surface. Figure 4 shows the general setup for the PVS-7D AGC measurements.

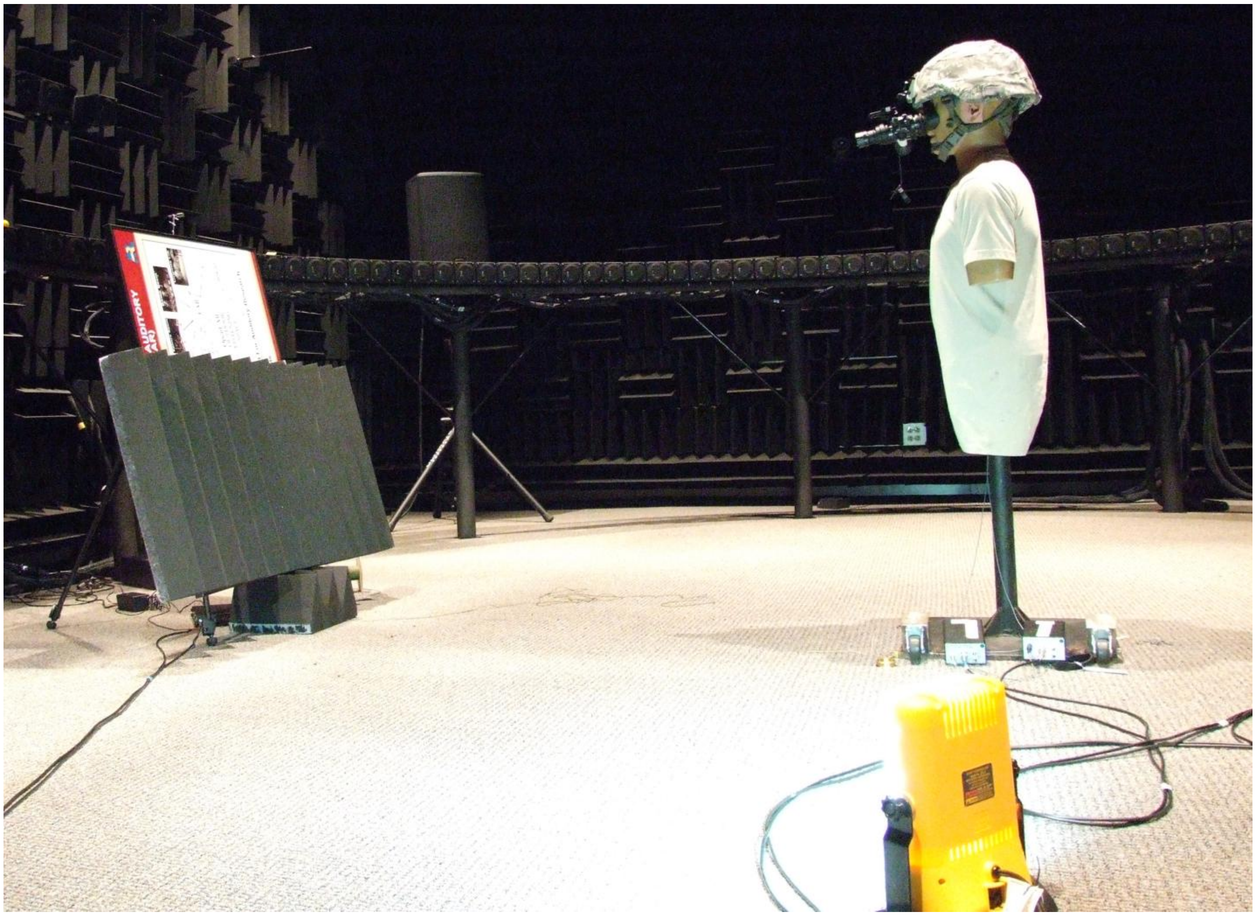

Figure 4. PVS-7D measurement in AGC mode.

3. Results

3.1 General Analysis

All sound files were submitted to a 1/3-octave band analysis in MATLAB. The design of the 1/3-octave filters was in accordance with ANSI S1.11 (2009). The analysis segmented the sound files into successive 125-ms-long windows. For each of these analysis windows, sound levels were calculated for each 1/3 octave, each octave, and the overall level in dB SPL. Finally, the average level across each time window was calculated for each 1/3 octave. These 1/3-octave values were then compared with MIL-STD-1474D level II aural nondetectability limits. Table 1 summarizes 1/3-octave band levels for ambient measurements by the 40-AF microphones in the Dome Room. Table 2 summarizes the ambient levels measure at KEMAR's ears. While it is not appropriate to evaluate aural nondetectability limits at KEMAR's ears because of the measurement distances, these measurements give a good indication of the sound levels as they are at the listener's ears.

Table 1. Ambient levels for each 1/3-octave band represent the Dome Room noise floor. Level II aural nondetectability limits and level II ambient levels are listed on the left. Measurements were taken at two locations (0° and 180°) and the average is listed on the right with standard errors (SEs).

Measurement Angle						
Analyzed 1/3 Octaves	Level II Limits	Level II Ambient	0°	180°	Average	SE
25	—	—	42.23	42.66	42.45	0.30
31.5	—	—	32.78	33.45	33.12	0.47
40	—	—	33.72	40.35	37.03	4.69
50	53	29	30.16	30.91	30.53	0.53
63	46	29	19.02	20.98	20.00	1.38
80	39	28	18.11	21.30	19.71	2.26
100	35	26	16.53	18.11	17.32	1.12
125	29	24	13.98	17.10	15.54	2.21
160	27	23	8.41	8.97	8.69	0.39
200	32	21	6.62	7.32	6.97	0.50
250	35	19	8.71	8.87	8.79	0.11
315	37	18	3.00	3.39	3.19	0.27
400	34	16	4.05	4.48	4.26	0.30
500	33	15	1.88	1.86	1.87	0.01
630	27	14	1.34	1.16	1.25	0.13
800	21	13	1.69	1.77	1.73	0.06
1,000	19	12	2.84	2.81	2.82	0.02
1,250	21	11	3.10	3.15	3.12	0.04
1,600	22	10	4.01	3.87	3.94	0.10
2,000	16	9	4.94	4.67	4.80	0.19
2,500	18	8	5.46	5.35	5.41	0.08
3,150	13	7	6.23	6.24	6.24	0.01
4,000	14	7	6.90	6.84	6.87	0.05
5,000	13	6	7.44	7.47	7.45	0.02
6,300	20	6	7.90	7.87	7.89	0.03
8,000	30	6	8.36	8.39	8.37	0.02
10,000	31	6	8.66	8.72	8.69	0.05
12,500	—	—	9.06	9.11	9.08	0.03
16,000	—	—	9.65	9.59	9.62	0.04
20,000	—	—	9.89	9.90	9.90	0.01

Table 2. Ambient levels for the Dome Room measured at KEMAR's ears for each 1/3 octave with center frequency labeled on the left. Measurement angles reflect the match to 40-AF microphone positions during the four recordings. Averages of the two measurements are listed on the right with SEs.

KEMAR: Measurement Angle (°) and Ear				
Analyzed 1/3 Octaves	0–180 (L_{ear})	0–180 (R_{ear})	Average	SE
25	19.33	18.94	19.13	0.28
31.5	20.65	18.94	19.80	1.21
40	25.16	24.55	24.85	0.43
50	24.70	24.31	24.50	0.28
63	22.55	21.18	21.86	0.97
80	21.26	19.85	20.56	1.00
100	20.32	18.85	19.59	1.04
125	17.58	16.71	17.15	0.62
160	16.37	15.83	16.10	0.38
200	15.90	15.43	15.66	0.33
250	17.10	16.21	16.66	0.63
315	14.25	13.84	14.04	0.29
400	14.36	13.20	13.78	0.82
500	13.35	12.23	12.79	0.80
630	13.03	12.02	12.52	0.72
800	12.63	11.94	12.28	0.48
1,000	12.45	11.69	12.07	0.53
1,250	12.46	11.62	12.04	0.59
1,600	12.51	11.54	12.03	0.69
2,000	13.16	12.24	12.70	0.65
2,500	13.64	12.85	13.25	0.56
3,150	14.00	13.31	13.66	0.49
4,000	14.45	13.20	13.82	0.88
5,000	15.07	13.86	14.46	0.86
6,300	15.81	14.59	15.20	0.86
8,000	16.60	15.90	16.25	0.49
10,000	17.48	16.10	16.79	0.98
12,500	18.32	16.79	17.56	1.08
16,000	18.75	17.36	18.06	0.98
20,000	19.37	18.03	18.70	0.94

3.1.1 PVS-14

In both the linear and AGC modes, PVS-14 noise levels did not exceed level II nondetectability limits for detection at 10 m. Tables 3 and 4 summarize the measurements at the eight 40-AF microphone positions against the level II criteria for the linear and AGC modes, respectively.

Tables 5 and 6 show the levels at KEMAR's ears for both the linear and AGC modes, respectively. Note that in both modes there is a very soft, but possibly audible tone at the 1/3 octave centered at 2 kHz. This would be audible to a user only because of the very close proximity of the device the user's ears. Also note that the level is greater in the left ear. This tone would not be detectable at any appreciable distance, as evidenced by the very low levels measured in this 1/3 octave at the 40-AF microphones for either the linear or AGC mode (see tables 3 and 4).

Table 3. Levels for the PVS-14 in linear mode measured 2 m from the device for each 1/3 octave with center frequency labeled on the left.

Measurement Angle (°)									
Analyzed 1/3 Octaves	Level II Limits	0	45	90	135	180	225	270	315
25	—	41.79	42.20	43.04	41.77	40.70	40.17	42.19	42.60
31.5	—	33.86	32.45	32.78	32.45	31.88	32.39	33.26	33.70
40	—	40.94	33.77	33.83	36.12	36.53	33.57	35.83	40.91
50	53	31.16	29.87	28.65	27.73	27.89	30.07	30.91	30.48
63	46	21.46	19.51	22.40	19.71	20.28	20.41	30.38	20.57
80	39	21.99	17.87	18.68	21.94	22.05	19.87	19.94	22.45
100	35	17.17	20.37	19.28	19.45	19.45	20.22	18.83	17.47
125	29	14.30	13.76	14.28	13.50	14.17	13.62	11.77	11.77
160	27	8.83	8.45	8.75	8.09	8.49	8.98	8.19	7.69
200	32	7.39	6.75	7.12	6.25	6.95	7.43	7.68	7.13
250	35	7.83	6.73	6.27	6.82	8.39	11.80	12.50	11.53
315	37	2.61	3.62	4.20	3.70	3.86	2.48	2.36	2.17
400	34	2.33	3.43	3.47	2.72	3.59	2.29	2.11	1.84
500	33	2.38	1.66	2.05	1.28	2.22	2.15	1.92	2.19
630	27	1.47	0.64	1.39	0.69	1.25	1.03	1.06	0.97
800	21	1.67	1.26	1.97	1.26	1.50	1.52	1.55	1.56
1,000	19	2.79	2.28	2.90	2.33	2.35	2.77	2.88	2.97
1,250	21	3.14	2.60	3.14	2.48	2.59	2.92	2.98	3.04
1,600	22	3.87	3.37	3.74	3.44	3.44	3.92	3.87	3.79
2,000	16	4.67	4.47	4.51	4.24	4.17	5.00	4.73	4.93
2,500	18	5.52	4.91	5.19	4.94	4.92	5.48	5.45	5.46
3,150	13	6.26	5.68	5.88	5.66	5.72	6.19	6.21	6.30
4,000	14	6.89	6.39	6.51	6.31	6.37	6.95	6.90	6.96
5,000	13	7.44	6.94	7.08	6.93	6.96	7.50	7.42	7.47
6,300	20	7.93	7.64	7.57	7.36	7.40	8.04	7.98	7.94
8,000	30	8.30	7.76	7.86	7.79	7.81	8.34	8.32	8.33
10,000	31	8.70	8.09	8.11	8.05	8.04	8.66	8.68	8.68
12,500	—	9.11	8.40	8.45	8.36	8.37	9.11	9.12	9.11
16,000	—	9.70	8.89	9.09	9.18	8.84	9.52	9.67	9.50
20,000	—	9.94	8.89	8.95	9.01	8.88	9.87	9.92	9.90

Table 4. Levels for the PVS-14 in AGC mode measured 2 m from the device for each 1/3 octave with center frequency labeled on the left.

		Measurement Angle (°)							
Analyzed 1/3 Octaves	Level II Limits	0	45	90	135	180	225	270	315
25	—	43.02	44.35	43.13	41.87	42.68	41.95	42.47	42.52
31.5	—	32.71	32.44	31.85	32.40	31.66	32.19	32.34	32.77
40	—	33.17	34.43	31.83	31.62	31.09	35.87	32.73	34.05
50	53	30.52	31.18	27.53	28.50	26.98	32.41	28.75	30.47
63	46	22.53	19.59	20.55	25.80	27.62	19.66	27.69	26.80
80	39	18.42	17.73	18.83	20.89	20.43	20.43	19.15	19.39
100	35	16.58	18.11	18.75	19.51	19.22	20.06	18.61	17.71
125	29	12.04	13.09	13.20	12.68	13.60	13.22	12.92	12.58
160	27	8.52	8.18	8.49	9.08	9.07	8.71	8.49	8.55
200	32	7.05	7.11	6.49	6.77	6.87	7.78	7.20	7.53
250	35	9.67	8.13	6.12	6.23	6.93	10.51	9.94	9.50
315	37	2.88	3.91	3.50	3.40	3.47	3.13	2.57	2.59
400	34	3.07	3.52	2.81	2.63	2.81	3.03	2.22	2.75
500	33	1.76	1.87	1.24	1.09	1.13	2.43	1.84	1.81
630	27	1.23	0.92	0.78	0.84	0.58	1.37	1.41	1.37
800	21	1.65	1.38	1.08	1.15	1.20	1.82	1.56	1.70
1,000	19	2.84	2.52	2.35	2.18	2.34	2.74	2.92	2.72
1,250	21	3.01	2.52	2.45	2.52	2.46	3.11	3.00	2.94
1,600	22	3.88	3.38	3.39	3.28	3.33	3.78	3.68	3.72
2,000	16	5.16	4.47	4.18	4.15	4.28	5.08	4.85	4.92
2,500	18	5.42	5.02	5.03	4.85	4.84	5.51	5.51	5.49
3,150	13	6.30	5.77	5.83	5.74	5.76	6.23	6.28	6.38
4,000	14	7.00	6.45	6.38	6.43	6.43	6.88	7.00	6.87
5,000	13	7.51	6.91	6.89	6.97	6.97	7.41	7.43	7.36
6,300	20	7.92	7.37	7.40	7.41	7.43	7.88	7.99	7.93
8,000	30	8.32	7.76	7.77	7.80	7.79	8.36	8.32	8.32
10,000	31	8.67	8.06	8.11	8.11	8.06	8.67	8.69	8.66
12,500	—	9.10	8.39	8.42	8.43	8.36	9.06	9.11	9.16
16,000	—	9.57	9.44	8.75	9.02	9.12	9.53	9.63	9.67
20,000	—	9.88	9.10	8.90	8.95	8.97	9.88	9.92	9.96

Table 5. Levels for the PVS-14 in linear mode measured at KEMAR's ears for each 1/3 octave with center frequency labeled on the left. Only the average is shown for the left and right ears with SEs. There was a soft tone at the 1/3-octave band centered at 2000 Hz, shown in bold and highlighted in grey.

KEMAR: Measurement Angle and Ear				
Analyzed 1/3 Octaves	(L_{ear}) Average	(L_{ear}) SE	(R_{ear}) Average	(R_{ear}) SE
25	22.67	1.42	22.42	2.14
31.5	21.63	0.91	20.59	0.21
40	27.34	1.20	26.47	1.62
50	25.16	0.34	23.98	0.50
63	23.38	0.29	22.49	0.27
80	21.25	0.34	20.37	0.30
100	20.49	0.07	19.08	0.49
125	17.75	0.35	16.85	0.22
160	16.87	0.18	16.34	0.15
200	16.36	0.18	15.67	0.33
250	15.66	0.31	14.77	0.32
315	14.67	0.07	13.77	0.18
400	14.07	0.21	13.35	0.11
500	13.35	0.19	12.59	0.14
630	12.99	0.09	12.06	0.14
800	12.58	0.05	11.72	0.11
1,000	12.63	0.04	11.57	0.02
1,250	12.50	0.05	11.45	0.10
1,600	12.81	0.17	11.59	0.08
2,000	**21.37**	**1.18**	**15.98**	**2.48**
2,500	14.53	0.69	12.61	0.35
3,150	16.78	1.92	15.94	2.21
4,000	15.07	0.59	13.12	0.01
5,000	15.56	0.36	13.74	0.02
6,300	18.35	4.39	14.87	0.85
8,000	16.69	0.11	15.26	0.05
10,000	17.53	0.04	16.14	0.05
12,500	18.64	0.23	16.83	0.01
16,000	18.82	0.04	17.40	0.03
20,000	19.38	0.01	18.07	0.01

Table 6. Levels for the PVS-14 in AGC mode measured at KEMAR's ears for each 1/3 octave with center frequency labeled on the left.

KEMAR: Measurement Angle and Ear				
Analyzed 1/3 Octaves	(L_{ear}) Average	(L_{ear}) SE	(R_{ear}) Ave	(R_{ear}) SE
25	22.47	0.97	22.66	0.43
31.5	21.18	0.51	20.98	0.17
40	26.05	1.19	25.18	1.18
50	26.07	0.97	25.06	1.05
63	25.07	2.45	24.82	2.75
80	21.28	0.13	20.55	0.47
100	20.43	0.13	19.28	0.30
125	17.62	0.19	16.77	0.24
160	16.72	0.16	16.16	0.31
200	16.29	0.17	15.59	0.15
250	15.58	0.11	14.75	0.16
315	14.43	0.11	13.73	0.13
400	14.00	0.17	13.29	0.12
500	13.32	0.14	12.53	0.16
630	12.84	0.05	12.07	0.12
800	12.57	0.05	11.71	0.04
1,000	12.63	0.10	11.65	0.05
1,250	12.43	0.04	11.44	0.09
1,600	12.88	0.13	11.59	0.06
2,000	**24.70**	**0.96**	**15.52**	**1.02**
2,500	15.01	0.30	12.77	0.06
3,150	18.40	1.01	18.44	0.22
4,000	16.15	0.32	13.19	0.02
5,000	15.34	0.07	13.74	0.05
6,300	16.35	0.52	14.62	0.10
8,000	16.83	0.05	15.47	0.03
10,000	17.58	0.02	16.12	0.03
12,500	18.58	0.03	16.84	0.03
16,000	18.82	0.02	17.40	0.01
20,000	19.38	0.03	18.06	0.01

3.1.2 PVS-7D

3.1.2.1 Linear Mode. In the linear mode, the PVS-7D did not exceed level II aural nondetectability limits at 10 m. Table 7 summarizes the measurements at the eight 40-AF microphone positions against the level II criteria for the linear mode, and table 8 summarizes the levels at KEMAR's ears for the linear mode. Like found for the PVS-14, there is a soft tone at the 1/3 octave centered at 2 kHz.

Table 7. Levels for the PVS-7D in linear mode measured 2 m from the device for each 1/3 octave with center frequency labeled on the left.

		Measurement Angle (°)							
Analyzed 1/3 Octaves	Level II Limits	0	45	90	135	180	225	270	315
25	—	40.59	40.40	40.56	39.26	40.93	38.82	39.51	41.18
31.5	—	33.46	32.70	31.70	32.55	30.94	33.46	33.68	33.34
40	—	36.11	31.96	32.64	31.73	32.93	34.59	35.21	34.05
50	53	30.87	29.48	27.15	28.40	28.33	29.94	29.09	29.87
63	46	26.72	25.87	18.80	20.93	21.93	27.16	20.28	27.92
80	39	19.20	18.28	19.01	20.17	20.91	20.67	21.31	19.13
100	35	17.43	18.05	18.59	19.74	19.85	19.41	18.58	17.50
125	29	12.22	14.09	13.78	13.29	12.82	13.22	12.81	12.71
160	27	8.70	9.16	8.96	9.10	8.61	8.64	8.17	8.91
200	32	6.89	6.77	6.46	7.37	6.42	7.80	7.04	7.04
250	35	10.70	7.75	7.09	7.94	7.92	10.75	10.39	10.62
315	37	3.27	4.18	3.45	4.70	3.22	3.34	2.98	4.44
400	34	3.97	3.54	3.03	4.23	2.99	3.98	3.64	5.14
500	33	1.44	1.99	1.42	2.22	1.27	1.88	1.54	2.43
630	27	1.36	1.25	0.81	1.80	0.94	1.68	1.14	2.06
800	21	1.72	1.58	1.28	2.22	1.25	2.07	1.64	2.74
1,000	19	3.03	2.54	2.44	3.41	2.48	3.17	2.95	3.83
1,250	21	3.28	2.78	2.62	3.75	2.64	3.22	3.11	3.92
1,600	22	3.93	3.50	3.47	4.44	3.45	4.01	4.06	4.76
2,000	16	4.81	4.30	4.26	5.07	4.22	4.92	4.84	5.60
2,500	18	5.47	5.08	5.11	5.71	4.99	5.61	5.54	6.21
3,150	13	6.32	5.84	5.79	6.34	5.85	6.39	6.33	6.77
4,000	14	6.92	6.56	6.53	6.85	6.48	6.94	6.88	7.24
5,000	13	7.48	7.13	7.06	7.39	7.09	7.60	7.40	7.88
6,300	20	8.00	7.59	7.50	7.85	7.62	8.03	8.00	8.24
8,000	30	8.44	7.95	7.93	8.11	7.97	8.38	8.40	8.52
10,000	31	8.71	8.29	8.26	8.30	8.28	8.78	8.79	8.76
12,500	—	9.16	8.64	8.60	8.63	8.60	9.14	9.18	9.18
16,000	—	9.78	9.15	8.85	9.23	9.33	9.65	9.61	9.90
20,000	—	10.01	9.11	9.07	9.17	9.24	10.01	9.96	10.07

Table 8. Levels for the PVS-7D in linear mode measured at KEMAR's ears for each 1/3 octave with center frequency labeled on the left.

KEMAR: Measurement Angle and Ear				
Analyzed 1/3 Octaves	(L_{ear}) Average	(L_{ear}) SE	(R_{ear}) Average	(R_{ear}) SE
25	22.67	1.42	22.42	2.14
31.5	21.63	0.91	20.59	0.21
40	27.34	1.20	26.47	1.62
50	25.16	0.34	23.98	0.50
63	23.38	0.29	22.49	0.27
80	21.25	0.34	20.37	0.30
100	20.49	0.07	19.08	0.49
125	17.75	0.35	16.85	0.22
160	16.87	0.18	16.34	0.15
200	16.36	0.18	15.67	0.33
250	15.66	0.31	14.77	0.32
315	14.67	0.07	13.77	0.18
400	14.07	0.21	13.35	0.11
500	13.35	0.19	12.59	0.14
630	12.99	0.09	12.06	0.14
800	12.58	0.05	11.72	0.11
1,000	12.63	0.04	11.57	0.02
1,250	12.50	0.05	11.45	0.10
1,600	12.81	0.17	11.59	0.08
2,000	**21.37**	**1.18**	**15.98**	**2.48**
2,500	14.53	0.69	12.61	0.35
3,150	16.78	1.92	15.94	2.21
4,000	15.07	0.59	13.12	0.01
5,000	15.56	0.36	13.74	0.02
6,300	18.35	4.39	14.87	0.85
8,000	16.69	0.11	15.26	0.05
10,000	17.53	0.04	16.14	0.05
12,500	18.64	0.23	16.83	0.01
16,000	18.82	0.04	17.40	0.03
20,000	19.38	0.01	18.07	0.01

3.1.2.2 AGC Mode. In the AGC mode, the data tell a very different story. Table 9 summarizes the measurements at the eight 40-AF microphone positions against the level II criteria for the AGC mode. Somewhat different from other analyzed conditions, there is energy at the 1/3-octave bands centered at 2 and 2.5 kHz. In this mode, PVS-7D levels exceed level II aural nondetectability in several cases. There are four measurements at the 1/3-octave band centered at 2 kHz that fail to meet level II limits for 10 M, and one measurement at the 1/3-octave band centered at 2.5 kHz that failed to meet level II limits. Although the device did not meet level II criteria in these five instances, in no case did the measurements exceed level II limits at 20 m, although the 225º measurement in the 2-kHz band comes very close with a level of 22.99 dB (level II limit at 20 m = 23 dB).

In table 9 there appears to be a significant difference in level across measurement angles; however, this conclusion must be tempered by the fact that there was some variability in the level of the signal between the four independent measurements. The KEMAR recordings give a reliable reference to see how the signal changed since the position of KEMAR's ear relative to the device never changed between measurements. Between the lowest recorded level and the highest level measured in the 2-kHz band, there is a greater than 9-dB variation in level. Because the device position never changes position with respect to the KEMAR microphones, the variation in level is entirely due to variability in device level across measurements. Table 10 shows how the signal changed across measurements. Note that there is a moderately intense signal in the 1/3-octave bands centered at both 2 and 2.5 kHz. Looking at the average levels across the right and left ear, we see that the signal is now greatest in the right ear.

Table 9. Levels for the PVS-7D in AGC mode measured 2 m from the device for each 1/3 octave with center frequency labeled on the left. Bold numbers with grey blocking indicate failures to meet level II criteria.

		Measurement Angle (°)							
Analyzed 1/3 Octaves	Level II Limits	0	45	90	135	180	225	270	315
25	—	40.29	40.83	40.43	40.14	40.59	38.58	39.77	40.34
31.5	—	35.76	31.86	33.51	30.61	32.96	33.84	34.82	33.01
40	—	35.50	33.50	31.02	30.95	31.84	34.76	33.40	33.68
50	53	30.27	28.98	27.31	27.49	27.16	29.86	29.48	29.17
63	46	29.51	20.90	21.39	18.59	28.25	26.97	22.00	20.35
80	39	19.32	17.26	18.63	19.28	20.63	19.68	18.59	18.34
100	35	17.56	17.96	18.55	19.21	19.45	19.26	18.34	17.49
125	29	11.98	14.76	15.89	17.40	16.34	13.06	13.73	12.67
160	27	9.37	8.59	9.25	9.56	8.80	8.26	9.05	8.81
200	32	7.37	6.77	6.96	7.23	7.29	7.03	7.49	7.63
250	35	11.46	8.52	9.79	10.61	11.40	5.88	10.26	11.20
315	37	3.32	3.81	4.29	4.17	4.04	3.57	3.53	3.62
400	34	3.77	2.99	4.72	4.47	4.33	4.73	4.56	4.31
500	33	2.05	1.99	1.66	1.64	1.55	2.16	1.82	2.08
630	27	1.30	1.30	0.79	0.97	0.82	1.26	1.19	1.20
800	21	1.82	1.34	1.33	1.25	1.15	1.75	1.61	1.74
1,000	19	3.24	2.55	2.23	2.34	2.40	3.09	3.05	3.03
1,250	21	3.51	2.79	2.74	2.98	2.86	3.16	3.34	3.38
1,600	22	4.21	3.63	3.39	3.41	3.47	4.62	4.06	4.01
2,000	16	**18.03**	**16.31**	10.56	6.21	**17.33**	**22.99**	13.76	13.29
2,500	18	14.26	12.61	8.13	5.71	13.58	**18.86**	10.70	10.31
3,150	13	6.46	5.94	5.80	5.73	5.85	6.60	6.37	6.38
4,000	14	7.61	7.02	7.23	6.48	6.67	8.98	7.31	7.04
5,000	13	7.81	7.53	7.29	6.96	7.06	8.24	7.59	7.59
6,300	20	8.14	7.55	7.51	7.52	7.50	8.03	7.98	8.04
8,000	30	8.50	7.87	7.84	7.82	7.85	8.49	8.43	8.44
10,000	31	8.80	8.18	8.13	8.11	8.15	8.80	8.79	8.79
12,500	—	9.21	8.52	8.47	8.45	8.47	9.22	9.19	9.21
16,000	—	9.69	8.84	9.00	8.93	9.05	9.85	9.64	9.77
20,000	—	10.02	8.98	9.04	9.00	9.05	10.07	10.02	10.03

Table 10. Levels for the PVS-7D in AGC mode measured at KEMAR's ears for each 1/3 octave with center frequency labeled on the left. Values for each measurement are listed for the left ear only. Averages with SEs are listed for both the right and left ear. There was a moderately intense tone at the 1/3-octave bands centered at 2000 and 2500 Hz, shown in bold and highlighted in grey.

KEMAR: Measurement Angle (°) and Ear								
Analyzed 1/3 Octaves	0–180 (L_{ear})	45–225 (L_{ear})	90–270 (L_{ear})	135–315 (L_{ear})	Average (L_{ear})	SE (L_{ear})	Average (R_{ear})	SE (R_{ear})
25	22.79	22.37	22.24	22.27	22.41	0.25	21.87	0.43
31.5	23.24	21.96	23.18	21.20	22.40	0.99	21.73	1.51
40	25.52	27.60	26.03	25.39	26.14	1.02	25.14	0.84
50	25.80	26.30	25.58	25.43	25.78	0.38	24.39	0.43
63	28.78	24.47	24.42	23.97	25.41	2.26	24.49	2.68
80	21.64	21.28	21.24	21.63	21.45	0.22	20.54	0.14
100	21.02	20.50	21.49	21.87	21.22	0.59	19.53	0.12
125	18.70	19.97	19.64	19.56	19.47	0.54	18.27	0.54
160	17.10	17.04	17.20	16.80	17.03	0.17	16.51	0.26
200	16.65	16.23	16.44	16.38	16.43	0.18	15.83	0.12
250	17.16	17.03	18.49	17.45	17.53	0.66	16.52	0.57
315	14.79	14.86	14.91	14.77	14.83	0.06	14.19	0.05
400	14.34	14.89	14.67	14.47	14.59	0.24	13.82	0.30
500	13.52	13.49	13.45	13.57	13.51	0.05	12.84	0.03
630	13.16	13.03	13.03	13.13	13.09	0.07	12.33	0.05
800	12.76	12.77	12.83	12.71	12.77	0.05	12.07	0.09
1,000	12.68	12.82	12.78	12.72	12.75	0.06	12.10	0.15
1,250	13.47	14.06	13.96	13.09	13.65	0.45	14.43	0.98
1,600	19.79	23.76	22.53	17.47	20.89	2.82	25.46	2.62
2,000	**46.16**	**50.85**	**49.40**	**41.71**	**47.03**	**4.92**	**52.58**	**3.29**
2,500	**41.97**	**46.60**	**45.21**	**37.62**	**42.85**	**3.99**	**48.38**	**2.86**
3,150	18.75	22.44	21.13	16.60	19.73	2.59	23.56	2.54
4,000	19.22	28.64	23.49	16.72	22.01	5.22	25.39	7.45
5,000	17.98	25.97	20.42	15.88	20.06	4.35	22.03	6.80
6,300	16.11	17.61	16.59	16.03	16.59	0.73	15.00	0.44
8,000	16.77	17.34	17.00	16.75	16.96	0.27	15.60	0.21
10,000	17.71	17.76	17.72	17.70	17.72	0.02	16.35	0.04
12,500	18.54	18.55	18.52	18.50	18.53	0.02	17.07	0.03
16,000	18.96	19.09	18.98	18.93	18.99	0.07	17.60	0.03
20,000	19.53	19.51	19.54	19.54	19.53	0.01	18.29	0.01

4. Conclusions

In all measurement cases (linear and AGC), the PVS-14 was predicted to be undetectable at an observation distance of 10 m. However, there was a faint tone that could potentially be heard only by the user. This tone was centered at 2 kHz and present during both linear and AGC modes. For the PVS-7D, whether the device met the aural nondetectability limits of MIL-STD-1474D depended on the mode of operation. In the linear mode, the device was predicted to not be detectable at an observation distance of 10 m. Like the PVS-14, the PVS-7D in linear mode emitted a faint tone centered at 2 kHz. In the AGC mode, the PVS-7D failed the level II aural nondetectable limits for 10 m in five cases (table 9). Thus, the PVS-7D tested in this evaluation is predicted to be detectable at an observation distance of 10 m. This result must be tempered by the fact that the audible tone in AGC mode is due to mechanical vibration produced by the autogating function of the image intensifier tube. There are a number of potential causes of the vibration; however, not all image intensifiers produce significant vibration when in AGC mode. Thus, although the present evaluation is relevant to the subset of devices tested here, in practice, aural nondetectability predictions may be quite variable across the family of systems. Indeed, in the present work there was significant variability in level even across individual measurements for the PVS-7D when in the ACG mode. It is thus not clear whether the same device is typically quieter than the measurements suggest, or whether it may even be more detectable under some circumstances.

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